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SM/I

SERVOMECHANISMS/INC.

RESEARCH AND DEVELOPMENT CENTER

Santa Barbara Airport, Goleta, California

MICROELECTRONIC CIRCUITRY IN
MICRO-MODULES

Contract: DA-36-039-SC-87316
Task: 3A99-15-002-03

Second Quarterly Progress Report
1 September 1961 to 31 November 1961

U.S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

". . . . . research and development work leading to the establishment of designs for digital type micro-modules and subassemblies employing advanced integrated circuit techniques . . . ."

Technical Requirement No. SCL-7576, dated 11 October 1960

H. Weber
S. Weld
L. Gille

SERVOMECHANISMS/ INC.
Advance Development & Engineering Division
Santa Barbara Airport
Goleta, California

Copy No. 34

TABLE OF CONTENTS

ILLUSTRATIONS

SECTION 1

PURPOSE

1.1 STATEMENT OF WORK

This contract calls for research and development work for a period of twelve (12) months, commencing 1 June 1961 and ending 31 May 1962, leading to the establishment of designs for digital-type micro-modules and subassemblies employing advanced integrated circuit techniques; and the fabrication of samples demonstrating the results of this research and development in accordance with Signal Corps Technical Requirement No. SCL-7576, dated 11 October 1960.

The technical requirement covers the design, fabrication, and evaluation of advanced-type digital micro-modules composed of micro-elements which incorporate latest advances in; (a) multi-layer thin-film circuitry, (b) solid-state integrated circuitry, and (c) semiconductor device packages. These advanced approaches will be combined to achieve a parts density of at least five times that available with current Army Signal Corps micro-modules. The capability to provide multiple circuit functions within single micro-modules which are mounted on assemblies of reduced size will be demonstrated.

1.2 DEVELOPMENTAL MODELS

Models representative of the work accomplished under 1.1 comprised of the following:

A. Ten (10) each of the three (3) types of circuit referred to in paragraph 3.1 of Signal Corps Technical Requirement No. SCL-7576, dated 11 October 1960.

These are:

1) Flip-Flop
2) Two Input Gate (ZC)
3) Driver Type B (ZE)

B. Three (3) each subassemblies of the type referred to in paragraph 3.7 through 3.7.4 of Signal Corps Technical Requirement No. SCL-7576, dated 11 October 1960.

Subassembly referred to here is air encoder board No. 2, as per Republic Aviation Company Drawing No. C84456.

The air encoder board subassembly shall be constructed from advanced-type micro-modules mounted on printed wiring boards.

1.3 TEST SETS

Four (4) each test set, one (1) set for each module and subassembly type selected under Item 1.2A and 1.2B above.

1.4 OBJECTIVES

The air encoder is a shift register consisting of 28 flip-flops, 3 drivers, and 1 gate. The air encoder has been analyzed and a general packaging configuration has been developed to accommodate this subassembly.

The circuit modules within the subassembly will be formed on standard .310 square, 12 notch micro-module glass wafers. The wafers shall be stacked over each other and encapsulated as conventional micro-modules; wafer-to-wafer integration shall be accomplished with vertical riser wires in the notches around the periphery of the module.

Single-ended modules having twelve (12) riser wires will be used.

Semiconductors used will be PMT 014 Pico transistors and PD 267 microdiodes manufactured by Pacific Semiconductors, Inc.

SECTION 2

ABSTRACT

This report describes the steps undertaken in the micro-miniaturization of a Signal Corps air encoder subassembly previously manufactured from standard components. The subassembly is a shift register consisting of 28 flip-flops, 1 gate, and 3 driver circuits. These circuits are to be vacuum deposited on .310 inch square glass substrates and then stacked into micro-modules .625 inches in height.

The techniques involved in monitoring the vacuum deposition of all films are discussed. A nichrome film is used in the deposition of resistors. Gold is used for the conductor pattern, interconnections, and capacitor plates. Silicon monoxide forms the capacitor dielectric and is also used as a protective coating for the resistors. The addition of active elements is required to complete the deposited passive circuit.

Discussed in this report is a multiprobe jig which makes contact to 22 terminals of a deposited flip-flop. This jig allows each wafer to be operationally tested before the active elements are attached. Each passive element on the wafer can also be selected and measured under static conditions.

Also discussed, is a mask changer under fabrication during this reporting period. This is a device to allow the changing of four masks without breaking vacuum. Maximum accumulated mask registration tolerance is ±.003 inches.

SECTION 3

FACTUAL DATA

3.1 SUMMARY OF WORK DONE THIS QUARTER

Monitoring techniques for the deposition of conductors, dielectric and resistors, have been greatly improved and are described in Section 3.2.

A two-part substrate holder has been developed. By the technique described in Section 3.3, this provides for the simultaneous alignment of all sixteen substrates in their correct positions with respect to the mask.

A multiprobe jig has been fabricated to accommodate the two-wafer flip-flop. This jig has 22 probes to contact key points on the wafer. Complete static and dynamic testing, as described in Section 3.4, can be performed rapidly with a minimum of effort.

In the First Quarterly Progress Report it was shown that the first 24 of the 28 flip-flops in this subassembly do not require set or reset leads. The last four flip-flops, however, require set and reset leads. The layout, art-work, and photography for the masks for the set-reset flip-flop were accomplished during this the second quarter, and are described in Section 3.5.

Several techniques pertaining to module assembly were investigated. One method considered provides independent spring tension for each of twelve riser wires during fabrication. A simpler approach to the module assembly jig, which has several advantages, was selected and is shown in Figure 1. By eliminating tension on the risers during all stages of module fabrication, a potential source of strain has been eliminated. In place of long wires under tension, short straight lengths of wire are used. This jig is easy to handle, easier to load, and may be hand-held or clamped in any position for various soldering techniques.

A mask changer which will permit the changing of four masks without breaking vacuum is nearing completion. This device is designed to a maximum accumulated mask registration tolerance of $\pm .003$ inches. Not only will considerable pump-down and cool-down time be saved in any production run, but the chances of contamination of films will be minimized. Capabilities, construction, and operation of the mask changer are discussed in Section 3.6.

3.2 MONITORING FILM THICKNESS

All films are monitored to a target value during the deposition process. For this purpose, two of the sixteen substrates on each mask are used exclusively for monitoring purposes.

Resistor films (nichrome) are monitored by measuring the resistance of an area consisting of ten squares during deposition. The deposition process is halted by the introduction of a shutter when the resistivity of the film reaches a predetermined value. Through the use of a known correction factor for the effects of heat treatment, cool-down, and aging, a final value of 250 ohms per square is obtained. Nominal thickness of the film is approximately 300 angstroms.

Conductor films (gold) are monitored in the same way as resistor films, using an area consisting of 100 squares, to a final value of 50 ohms. Conductor film is approximately 2700 angstroms thick.

Dielectric films (silicon monoxide) are monitored by measuring the absorption of light passing through the film as it is deposited on the second monitor substrate. Absorption is measured by the change in resistance of a photocell. When the thickness, approximately 13,500 angstroms, reaches a value which yields 25,000 micro-microfarads per square inch of capacitor plate area, the deposition is stopped by the introduction of a shutter.

3.3 NEWLY DEVELOPED SUBSTRATE HOLDER

It was necessary for the new 4-position mask changer to hold substrates from above without the aid of the mask to keep them from falling. To accomplish this, a new substrate holder was developed. Figure 2 is a photograph of the two parts of this new holder. Figure 3 is a photograph of the assembled holder loaded with sixteen substrates after deposition.

The principal requirements of this new holder were as follows: it must

1) Hold the substrates by edge pressure only,
2) Be no thicker than the substrates, and have no protrusions above or below the substrates' front or rear surfaces, and
3) Enable one man to conveniently load sixteen substrates into the holder without chipping their surfaces.

The two parts of this holder are photoetched beryllium-copper sheets that are placed on top of each other. Both sheets have sixteen areas etched through to receive the substrates. In the lower sheet, which is rigidly attached to a backing plate, these areas are provided with contacts to only two adjacent sides of the substrate;

clearance is provided for the other sides and all four corners. These fixed contact edges on the lower sheet reference the substrates with respect to the location holes in the holder. The holder then fits over locating pins seen pressed in the backing sheet in Figure 3. Deposition masks fit over these pins, and etched deposition patterns are thereby accurately registered with respect to the wafer.

All substrate fabrication dimensions are referenced to two edges of the substrate, identifiable by a notch on the substrate. The reference edges of the substrate can thereby be placed in contact with the location edges in the fixed lower sheet of the substrate holder.

The top sheet of the substrate holder provides clearance at all four corners of the substrate and at the two referenced edges. At the other two edges, etched spring fingers in the top sheet press against the substrate to hold the registration edges firmly against the location edges in the lower sheet. Requirement 1) above, is thus met.

In order to meet requirement 2), the top and bottom sheets are each etched from both sides using different patterns for each side. Both the location edges and the spring fingers are thereby made with a thickness of .020 inches. The thickness of the overlapping portions are each .010 inches for a combined thickness of .020 inches. The substrates are also .020 inches thick, thus presenting a flat surface against the mask.

One man can conveniently load sixteen substrates (requirement 3)). The top sheet can be moved diagonally relative to the bottom sheet in order to compress or relax the spring fingers. During substrate loading, the top sheet is in the retracted or relaxed position. After all substrates have been placed into the holder, the top sheet is slid diagonally, causing the spring fingers to press and align all substrates against their locating edges simultaneously. Holding the top sheet in this clamping position with one hand, the operator tightens the five screws that secure the top sheet, as shown in Figure 3. The holder, frame, and backing plate assembly can now be inverted without any substrates falling out.

3.4 MULTIPROBE JIG

In order to be sure that active elements are not attached to deposited circuits which have any electrical defect, each circuit must be tested before these components are attached. This testing requires a jig which will simultaneously contact all terminals on the microcircuit. Such a jig is shown in Figure 4. This top view shows the 22 probes contacting a 2-wafer flip-flop. Each .025-inch probe wire is aligned by a .028 hole, and thus comes down within a .0015-inch radius of the desired location each time the jig is operated. The jig is shown in the open position in Figure 5, which also shows the L-shaped alignment stop for the wafers, and the movable pusher-blocks by means of which the wafers are positioned against the alignment stop. The various switches and plugs enable the jig to test completely the micro-circuit both statically and dynamically.

To accommodate static testing, there are probes to contact both terminals of each resistor and each capacitor. By means of a 12-position switch, each passive element on the microcircuit can be switched successively to the appropriate meter. In this way, a complete set of data can easily be taken of every substrate. These tests serve to check on the accuracy and reproducibility of every step of fabrication, from layout and art-work to etching of masks and evaporation and aging of circuits. This complete check of the final wafer is vital to the preliminary stages of fabrication. However, it can be eliminated during a production run by dynamic testing described below.

To accommodate dynamic testing, there is a probe at each bonding terminal (for the connection of active elements), and at each external connection to the circuit. In this way, each wafer can be given a complete operational checkout before attachment of the semiconductors. During a production run of a given substrate, this can be abbreviated to a time-saving go-no-go test. In the case of the flip-flop, diodes and transistors are connected, supply and bias voltages are applied, and the microcircuit can be operationally checked by shifting information through a breadboarded 3-stage shift register. The semiconductors are soldered onto printed circuit plug-in cards for testing, as shown in Figure 5. The use of plug-in active elements on the multiprobe jig (and all breadboards) allows the circuits to be tested for compatibility with active elements of different parameters throughout the range which may be encountered.

As explained in the First Quarterly Report, flip-flops are deposited in two configurations. They differ by the interchange of the input and output leads to enable interconnections of the output of each flip-flop to the input of the succeeding flip-flop in the module to be made by vertical riser wires. Either configuration 1 or configuration 2 can be tested with the multi-probe jig by setting the switches to make the appropriate inter-connections. The switch to perform this function is labeled "1" and "2" in Figure 5. The other switch shown in this photograph is used to "set" the deposited flip-flop under test.

The individual probes are made of .025 phosphor-bronze wire bent in such a way that each provides its own independent spring tension. The contact tips were rounded and polished in a jeweler's lathe, and gold plated to prevent corrosion.

3.5 R-S-T FLIP-FLOP

Of the 28 flip-flops in the shift register, the first 24 do not require set or reset leads, as explained in the First Quarterly Report. These leads, therefore, were eliminated in order to allow four flip-flops to be stacked per module. Schematic diagrams of the trigger flip-flop and the R-S-T flip-flop are shown in Figures 6 and 7. The mask patterns for the R-S-T flip-flop are shown in Figures 8, 9 and 10.

The basic interconnection system previously explained is used on the R-S-T flip-flops - there are two wafers per flip-flop, and there are two types of flip-flop that differ in lead configuration. However, these R-S-T flip-flops cannot be stacked in a single four flip-flop module due to the increased number of external leads. This is in accordance with the packaging philosophy outlined in the First Quarterly Report.

3.6 4-POSITION MASK CHANGER

A device to enable the changing of masks under vacuum on four sets of substrates has been designed and its fabrication is nearing completion. One of four deposition stations will have a dielectric source, while the other three will have conductor sources. Each station has a deposition area of four square inches and will be provided with a different mask, whose location is fixed. A set of sixteen substrates will be located above each mask. These substrates can be rotated from station to station and will be precisely aligned at each station (within $\pm .003$ inches) by the location system described below.

The mask changer consists of two 22-inch diameter aluminum plates mounted horizontally, as shown in Figure 11. The bottom plate is called the stator and holds the masks, however it is free to rotate. The top plate is the rotor and holds the substrates and rear surface heaters.

When in operation, the stator is positioned so that the masks are directly above their respective evaporation sources. On the bottom side of each mask is an egg-crate stiffening support, which can be seen in Figures 11 and 12.

Each beryllium-copper deposition mask is precision located, and then permanently attached to a stainless-steel frame. This mask-frame assembly is then dropped into place on the stator and automatically located by jig-bore located pins in the stator and bushings in the mask frame. A mask assembly can be changed at any time by merely lifting out the old assembly and dropping in a new assembly.

The beryllium-copper substrate holder is likewise precision attached to a stainless-steel frame containing jig-bore located bushings. These bushings slide over the same stator pins that located the mask assembly. Registration of stator-mask assembly and rotor-substrate assembly is accomplished, then, by one set of hardened steel stator pins over which slide the hardened steel bushings in the mask frames and substrate-holder frames.

Rotary positioning of the rotor to the stator is accomplished by two additional sets of pins. A total of three sets of pins and bushings are engaged in sequence, starting with the set of least tight fit (which gives the operator his "feel"), then a set of tapered "lead-in" pins of moderately tight fit, and ending with the final closest fit between the substrate-holder frame and the mask frame. The first two sets of pin-bushing engagements serve to provide precision angular alignment of rotor to stator and to give the operator a location feel, while the third pin-bushing engagement serves to give the mask and substrate their final, high precision alignment. To facilitate this final alignment, the substrate-holder assembly is mounted to the rotor in such a way as to allow it a limited relative motion or self-aligning action.

The rotor must be lifted to disengage it from the stator before it can be rotated 90° for the next deposition. This lifting and rotating is accomplished by a rotor shaft protruding through a rotary high-vacuum shaft seal on the top cover of the vacuum chamber. A cam and lever provide the operator-controlled lifting for disengagement and serve as a crank for rotation.

The complete rotor and stator assembly is suspended from the top cover of the vacuum chamber by four rods. The cover and changer assembly is suspended by cables and pulleys from an overhead "gallows" and is balanced with counterweights.

Each of the four rear-surface substrate heaters, shown in Figures 11 and 12, plug into the rear of the rotor and substrate-holder assemblies. Double radiation shields of polished aluminum are on the back side of each heater. The heaters are made of kanthal wire strung through alumina rods which are mounted in a frame of glass-bonded synthetic mica. A thin glass plate separates the heater from the substrates.

Conductive film monitor-probe contacts are located on the stator. These probes are connected to ceramic terminal strips, and wires from the terminal strips are connected to octal plugs in the vacuum chamber cover. Also located on the stator are four iron-constantan thermocouples whose junctions make contact with the deposition mask at each of the four locations. Each junction is embedded in a well in the egg-crate mask support, between two deposition areas, and in the same relative location at each station. The temperatures indicated will be lower than the actual substrate temperature, but will be reproducible. Each thermocouple is read out on a separate meter, and each heater has a separate Variac control.

Metal parts that are expected to be of near equal temperature have been fabricated out of metals having the same temperature expansion coefficients. The masks and substrate holders and their stainless-steel mounting frames have thermal expansion coefficients of 16.7×10^{-6} in./in./°C (beryllium copper) and 16.0×10^{-6} in./in./°C (stainless steel). The egg-crate mask stiffeners are also made from beryllium copper. It should be noted that all of these will be directly irradiated by the heaters and will, therefore, be the hottest parts of the changer assembly.

The stator and rotor are both made from stretched, minimum stress aluminum plate (6061-T651) which has the higher expansion coefficient of 24.0×10^{-6} in./in./° C. The stator and rotor will always be cooler than the mask and substrate-holder assemblies, since they are not directly irradiated by the heaters.

After venting chamber to atmosphere, the cover with suspended changer assembly is raised, and the rotor is disengaged from the stator. The four heaters are unplugged from the back side of the substrate-holder assembly and laid aside elsewhere on the back of the rotor. The substrate-holder assemblies are now lifted off the back of the rotor and placed inside the "Sterilshield" clean box for removal of completed circuits and for loading of new substrates. The newly loaded holders will then be placed in their rotor positions, the heaters will be plugged into position, and the rotor will be engaged with the stator.

Before closing the chamber and pumping it to evaporation pressure, each evaporation source is reloaded with gold, nichrome, or silicon monoxide, in quantity sufficient for the four evaporations to be made from each source during the following evaporation cycle. Source shutters are all placed in the closed position. As soon as the chamber has been roughed, and has been valved to pump through the diffusion pump circuit, the heaters are turned on to start the substrate outgassing cycle. After an hour, substrate temperatures are adjusted to their desired values for evaporation at each station. The chamber pressure should now be about 5.0 x 10^{-6} mmHg.

When depositing the flip-flop circuits, evaporation station A has the mask for the first conductor, station B has the dielectric mask, station C has the final conductor mask for configuration 1, and station D has the final conductor mask for configuration 2.

Evaporation sequence proceeds as follows:

1) Evaporate at station A onto holder 1,
2) Turn rotor 90°,
3) Evaporate at station A onto holder 2,
4) Evaporate at station B onto holder 1,
5) Turn rotor 90°,
6) Evaporate at station A onto holder 3,
7) Evaporate at station B onto holder 2,
8) Evaporate at station C onto holder 1, etc.

Two of the holders will receive their final conductor at station C and the remaining two holders will receive their final conductor at station D. All films deposited are monitored for thickness. Depositions from an evaporating source are started and stopped by opening or closing a shutter between source and substrates. After all depositions have been made on all four sets of substrates, the heaters are turned off. When the substrates have cooled to about 50° C, they can be removed from the chamber, and a new cycle can be started.

3.7 SOLDERING OF RISER WIRES TO TAB AREA

The assembly of wafer sections to perform modular functions is to be accomplished by soldering riser wires to the deposited gold tab area of the glass substrate. The attachment of riser wires to the modules has been found to involve several problems. Most of these problems are associated with the fact that the present program involves connecting riser wires directly to deposited gold film terminals, whereas the conventional micro-module uses fired on silver terminals.

There are distinct advantages to the elimination of all materials other than thin films from the substrate. If some other material were used to form terminals, it would have to be applied before the vacuum deposition, since unprotected thin-film circuitry could not be subjected to the processes of application of such a material. These terminals would be, therefore, underneath the deposited film conductors. A source of trouble can be readily seen here; the terminal would be thicker than the conductor film by well over an order of magnitude. Thus, where the thin-film conductor comes up onto the thick terminal, a break in the conductor film is liable to occur. Previous experience with fired silver terminals has shown SM/I that these breaks often occur - if not immediately, then after moderate aging.

Based on investigations described in the First Quarterly Report, Microsheet glass has been selected as the substrate material. This glass is drawn to its final thickness and, therefore, has a surface quality equivalent to a fire-polished surface. The use of this glass in place of other glass substrate material has resulted in more reproducible resistors, more reproducible capacitors, and capacitors with less leakage and less erratic leakage.

The processes of application of any fired on terminals could easily cause noticeable reduction in the surface quality which these substrates possess.

The major problem in soldering directly to deposited gold films is that gold dissolves very rapidly in molten solder. Presently, a small Oryx "pencil" iron and .015 inch diameter solder with rosin flux are used. The flux causes the solder to flow to the limits of the terminal very quickly; formation of the solder joint is necessary in order that the solder will freeze before it dissolves all the gold from the terminal.

Occasionally solder will protrude from a riser enough that it would prevent the module from fitting into a potting shell. When an attempt is made to remove this solder, the remaining gold on the solder terminal will often be dissolved. When this happens, the solder will no longer wet the substrate, but will run back onto the riser wire, leaving an open circuit.

Another instance of gold being dissolved results from the following. Contact is made from the terminal to the circuit through either the resistor film, the first conductor film, or the second conductor film. In the first two cases, the path leading away from the terminal is generally covered with dielectric. However, if the path is formed by the final conductor, then it cannot be covered with dielectric. It has been found that in these cases there is a tendency for the solder to flow from the terminal out onto the conductor path and then return to the terminal, leaving the conductor path stripped of gold. Since the resulting open circuit is not necessarily visible, this phenomenon can lead to a lot of wasted time.

One may draw a conclusion by reviewing the progress and remaining problems. By selection of the optimum materials for the production of microcircuits - namely properly prepared glass substrates and the proper materials for deposition, we now anticipate reasonable yield and good reliability from our deposition chambers. However, the very choice of techniques that make for good microcircuits make the problem of wafer interconnection by riser wires more difficult. This problem will be given more emphasis in the next period.

SECTION 4

CONCLUSIONS

The work done this quarter has led to the following conclusions:

A. Technical details of monitoring have been worked out to enable accurate monitoring of every deposition.

B. All sixteen substrates can be simultaneously aligned and held from above by spring-tension edge contacts only using a new substrate holder.

C. The multiprobe jig has been fabricated and has successfully solved the problem of testing deposited circuits. This device, with 22 independent probes, enables measurement of each deposited passive element as well as allowing complete operational testing of the circuit. Plug-in connection of the active elements to this jig permits the evaluation of the microcircuit for compatibility with a variety of semiconductors.

D. The R-S-T flip-flop has been laid out according to the packaging scheme previously developed; these four flip-flops will be packaged in two modules. The layout, art-work, and photography stages were accomplished this quarter.

SECTION 5

PROGRAM FOR NEXT INTERVAL

5.1 CONTINUATION OF PRESENT WORK

A. Vacuum deposition of flip-flop circuit.

B. Evaluation of deposited passive elements in flip-flop circuit.

C. Attachment of semiconductors by thermo-compression bonding.

D. Dynamic testing of complete flip-flops, consisting of two wafers each.

E. Breadboard design of gate and driver circuits.

F. Temperature testing of breadboard circuits.

G. Mask layout for driver and gate.

H. Mask fabrication of driver and gate.

I. Bring to completion the fabrication of the mask changer. Install changer in vacuum chamber to replace existing facilities.

5.2 INITIATION OF NEW WORK

A. Design and build test sets for various modules.

B. Evaluate deposition processes through analysis of flip-flop deposition data.

C. Assemble modules according to previously described packaging philosophy.

SECTION 6

IDENTIFICATION OF KEY PERSONNEL

The following individuals took part in the work covered by this report (also see Table 6-1):

H. J. WEBER received his B.S.E.E. from Columbia University and has done graduate work at Columbia University and Adelphi College, specializing in pulse circuitry, digital computers, and transistor circuitry.

Prior to joining SM/I in 1957, Mr. Weber was employed at the Arma Division of American Bosch Arma Corporation where he was engaged in the design of a transistorized real-time digital computer.

Mr. Weber then joined the Reeves Instrument Corporation where he was responsible for the conception, design and development of a transistorized digital integrator for use in an inertial guidance system.

Since joining SM/I, Mr. Weber has been responsible for the complete design and development of microcircuitry; the pulse circuits associated with magnetic thin films; telemetering systems; and such projects as AGACS, DARTIC, and a Digital Motor Analyzer.

In his present position, he is responsible for electronic circuit development, vacuum deposition, and graphic arts.

Among his publications are the following:

> Inertial Guidance System Uses Digital Integrator,
> Space/Aeronautics - November 1958

Binary Circuits Count Backwards and Forwards,
Electronics - September 1959

Electrical Readout from Thin Ferromagnetic Films,
Electronics - July 1960

Analyzing Magnetically-Detented Stepper Servo Motors,
Electronics - September 1960

Design of Vacuum Deposited Microcircuitry,
Military Systems Design - January 1961

Thin Film Multivibrators,
Space/Aeronautics - August 1961

Bonding Microelements to Phenolic Board,
Electronics - November 1961

R. B. PUTZ received his B.S.M.E. from the University of Minnesota.

Mr. Putz has over twenty years design experience in precision mechanical devices and miniaturized electronic packaging. Research, development, and product design in the fields of aircraft, missile guidance, optical and medical. Electronic packaging for airborne radar, sonar, torpedo, target drone, telemetering, and data transmission.

Specific Areas of experience are:

A. Development of precision vacuum deposition masks for microminiature electronic components and circuits through the adaption of graphic arts methods and photo-chemical processes.

B. Microcircuit design and high density packaging of microminiature components for airborne electronics.

C. Automatic spray deposition of carbon film.

D. Telemetering commutators and brushes.

E. Photographic methods for producing close tolerance tooling by chemical milling.

F. Cameras and photographic equipment.

S. V. PETERTYL received his formal education at Michigan State College.

Prior to joining SM/I in 1958 he was employed as a product engineer and was responsible for the design of a precision optical comparator. He has been concerned with materials research in connection with such processes as casting, sintering and high temperature metallurgy.

At SM/I his efforts have been centered around the following projects:

A. Thin film transparent cathodoluminescent phosphors, and the problems encountered in their manufacture.

B. Development of high performance thin film photoconductors and electroluminescent devices.

C. Vacuum system design and development of magnetic thin films and microcircuits.

D. Thin film study of high resistivity carbides as circuit elements.

E. Film thickness measurements and evaluation of test results.

S. A. WELD received his B.A. in Physics from Rice Institute, and has done graduate work in Physics and Mathematics at the University of California at Santa Barbara.

Prior to joining SM/I, Mr. Weld worked at General Electric, TEMPO, as a Physicist. His areas of interest included masers, cryotrons and superconductivity.

At SM/I, Mr. Weld has been engaged in the development of microcircuitry - including instrumentation, environmental testing, aging, and circuit design.

L. A. GILLE received his B.A. at the University of California at Santa Barbara.

Mr. Gille was engaged in data reduction of underwater geophysical explorations at the United Geophysical Corporation before joining SM/I.

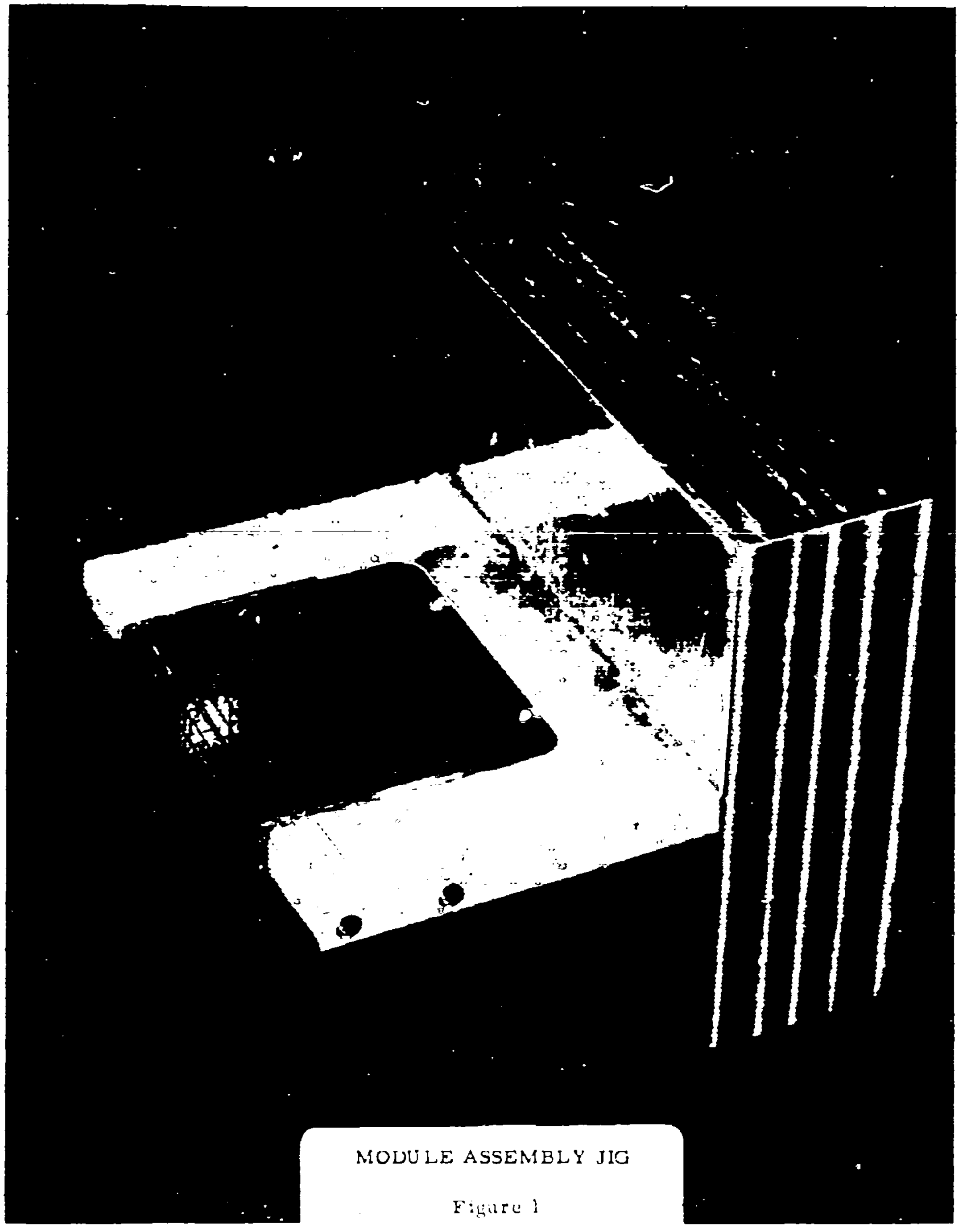
At SM/I, Mr. Gille has worked on the design and layout of microcircuitry packaging and deposition masking, and the related design of associated fixtures for deposition. He is also involved in the design of thin film magnetic and photoconductive devices.

TABLE 6-1

KEY TECHNICAL PERSONNEL

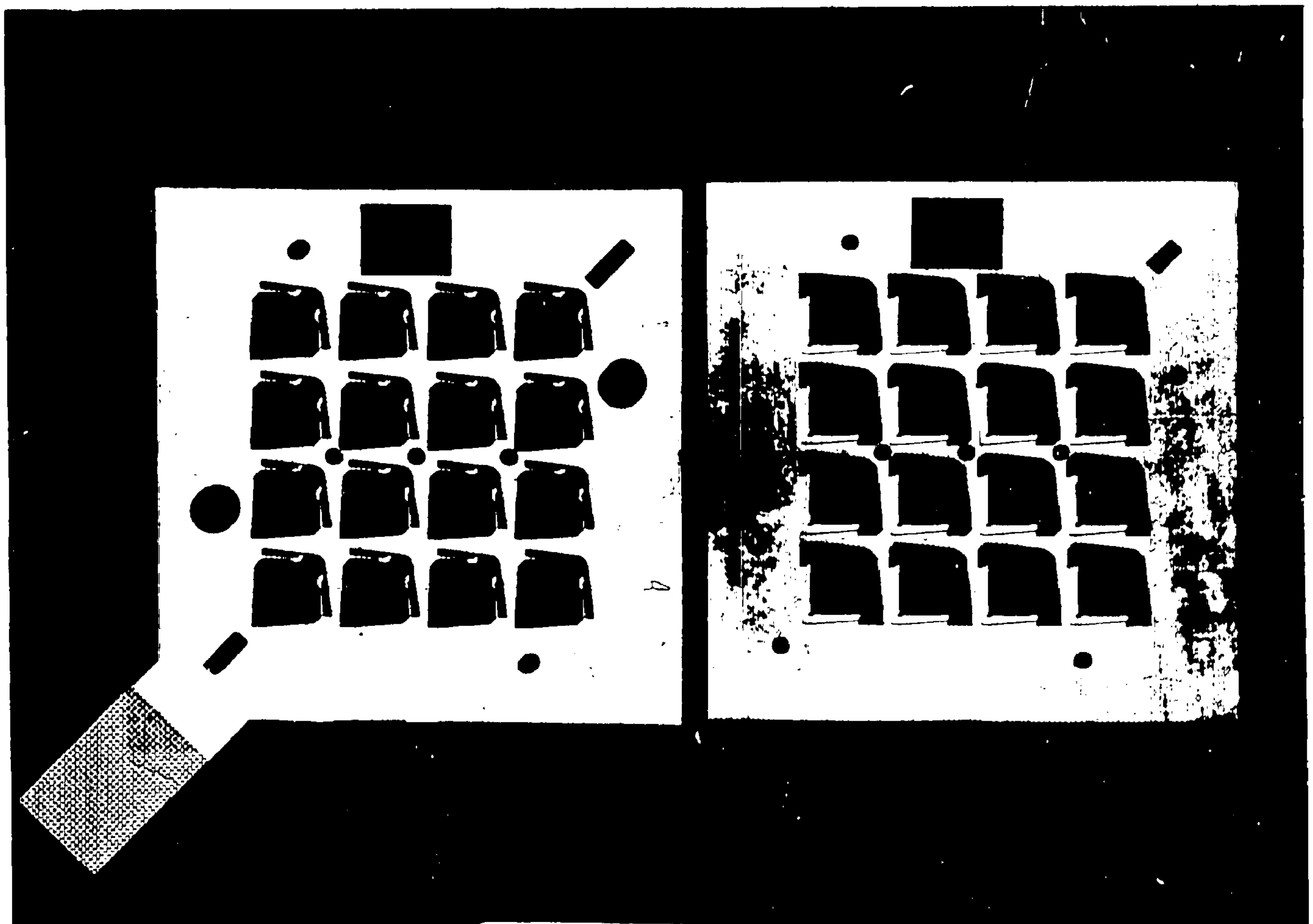
Name	Type	Man-Hours
H. J. Weber	Chief Development Engineer	*
R. B. Putz	Section Head, Graphic Arts	341
S. V. Petertyl	Section Head, Vacuum Laboratory	453
S. A. Weld	Development Engineer	464
L. A. Gille	Designer	360

* Mr. H. J. Weber is directing this program. His time, however, is normally charged to overhead.



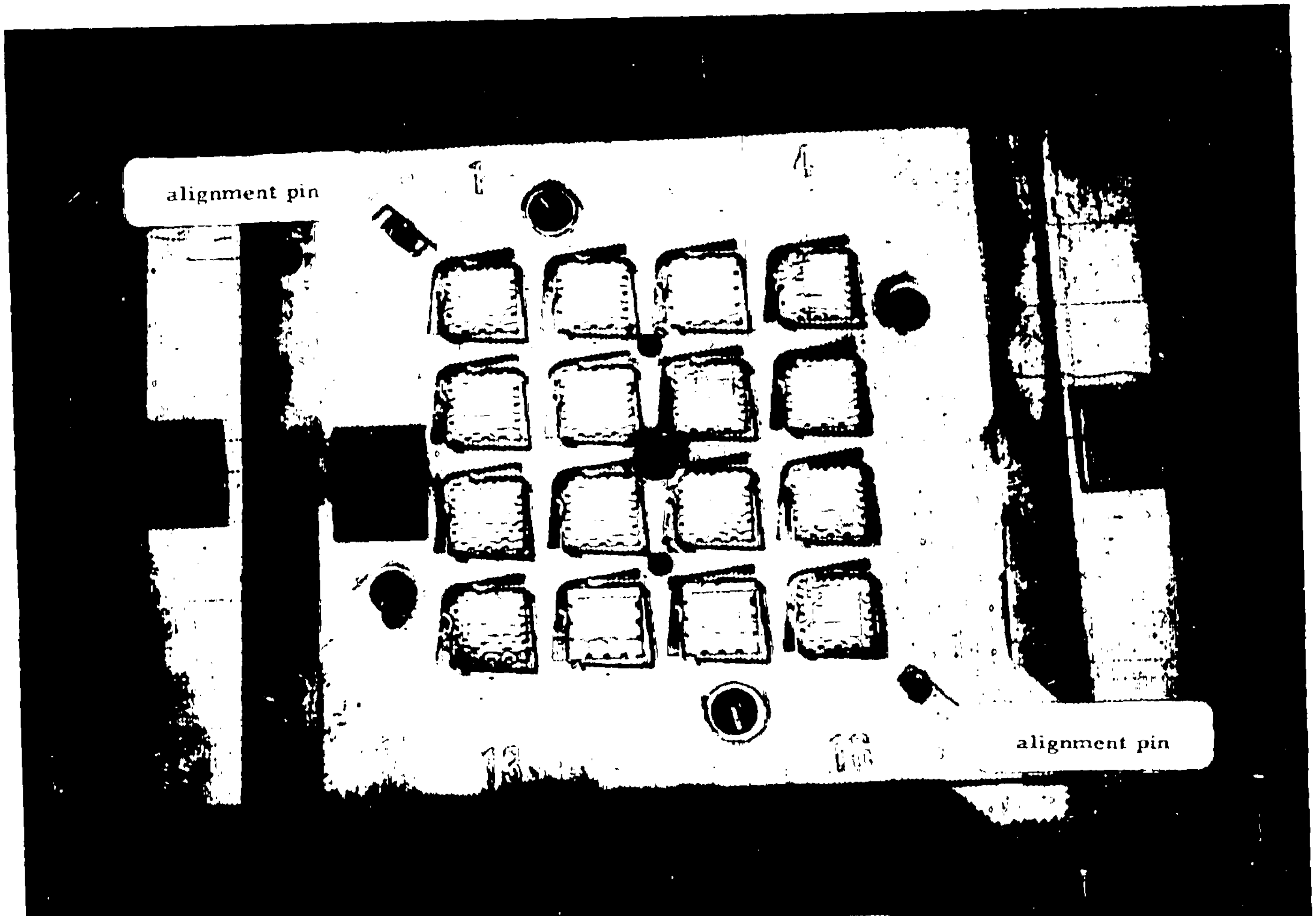
MODULE ASSEMBLY JIG

Figure 1



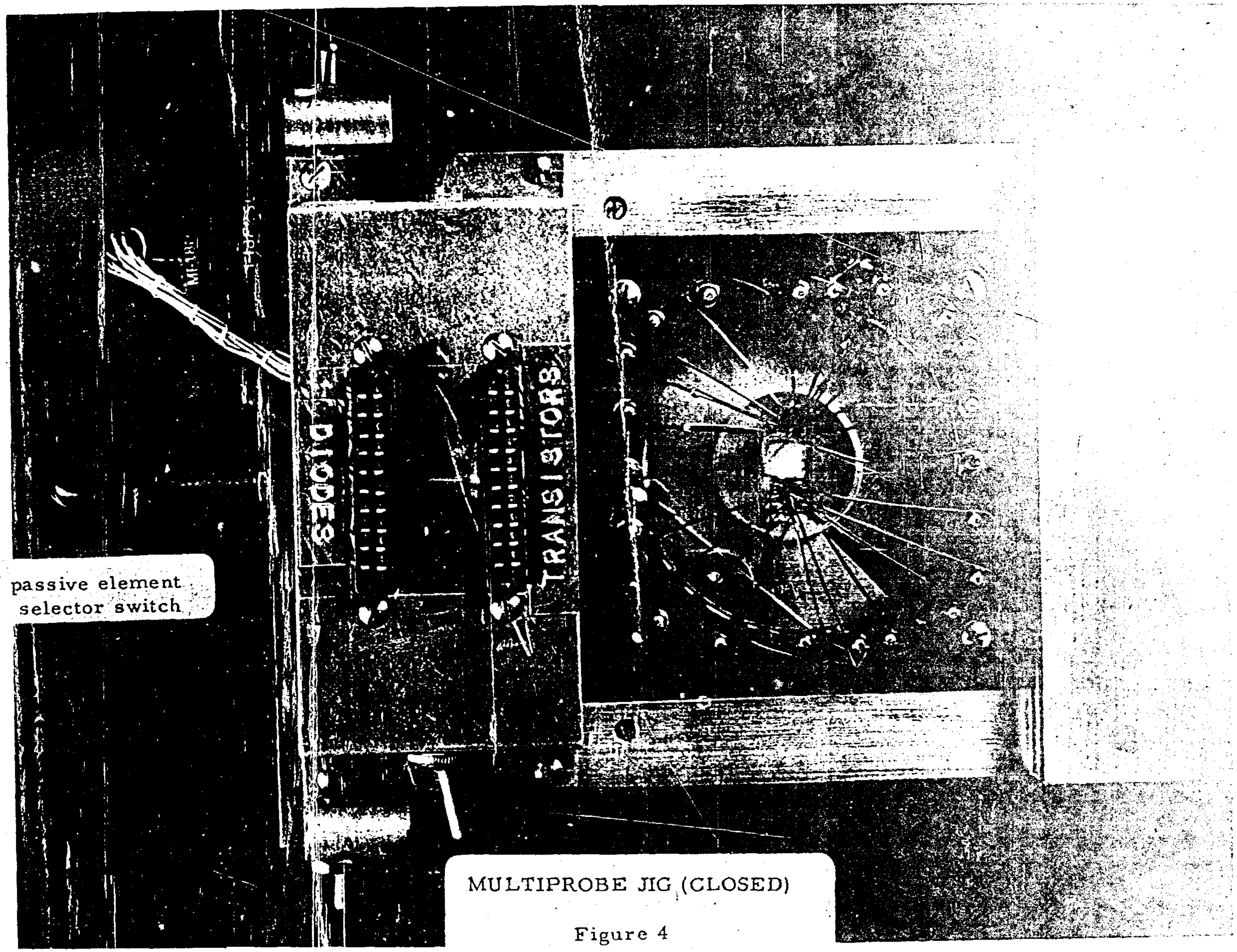
TWO PARTS OF
SUBSTRATE HOLDER

Figure 2



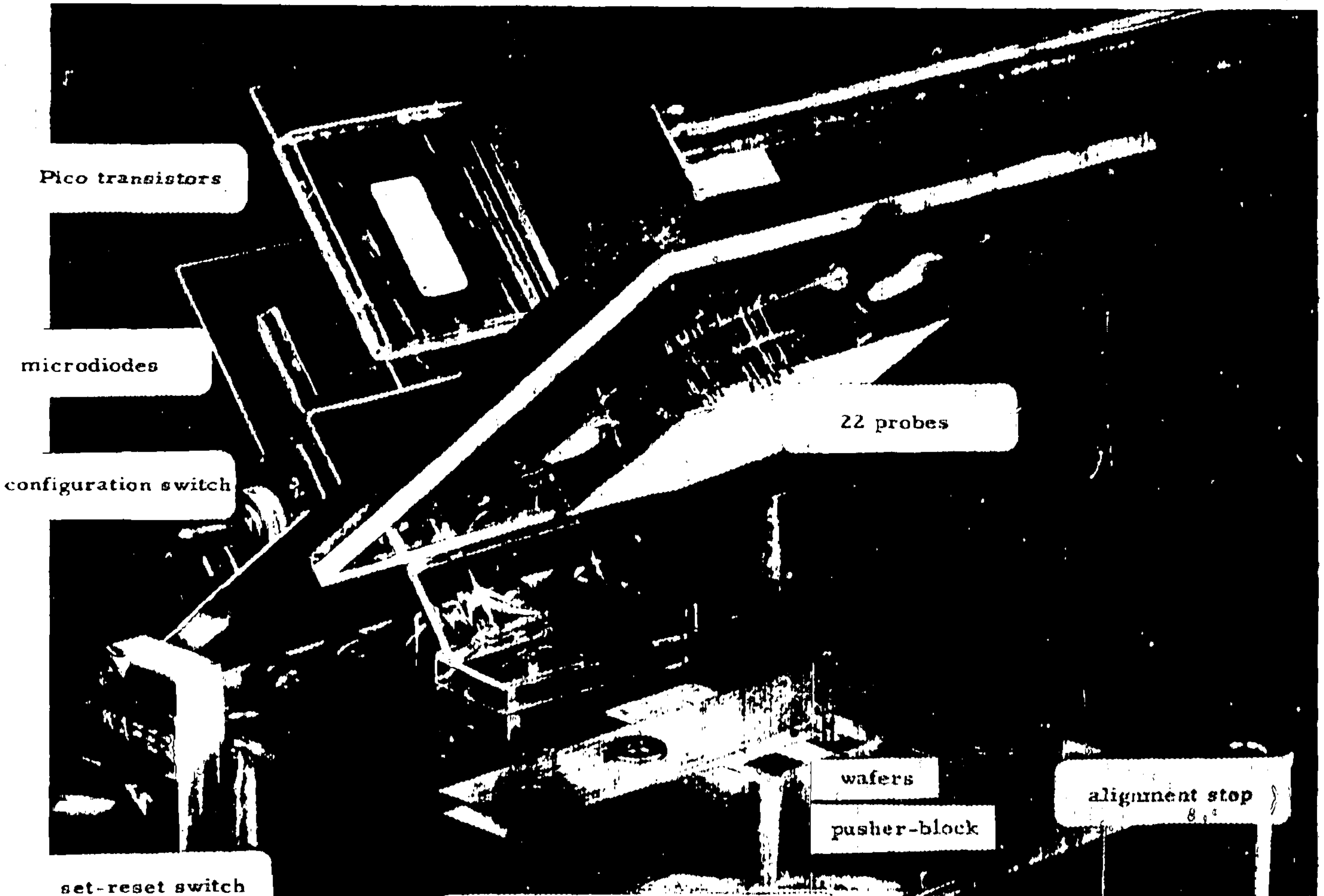
ASSEMBLED AND LOADED
SUBSTRATE HOLDER

Figure 3



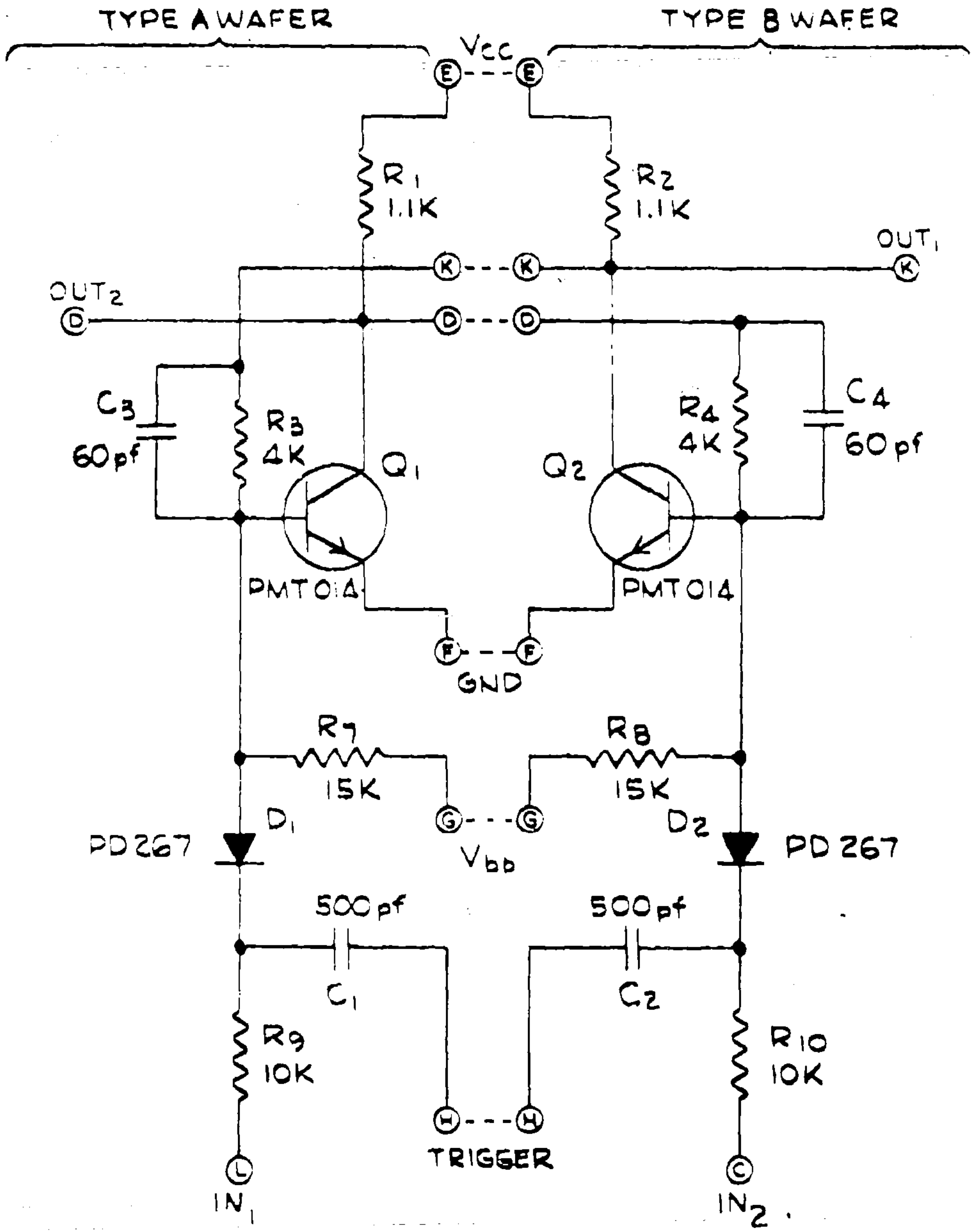
MULTIPROBE JIG (CLOSED)

Figure 4



MULTIPROBE JIG (OPEN)

Figure 5

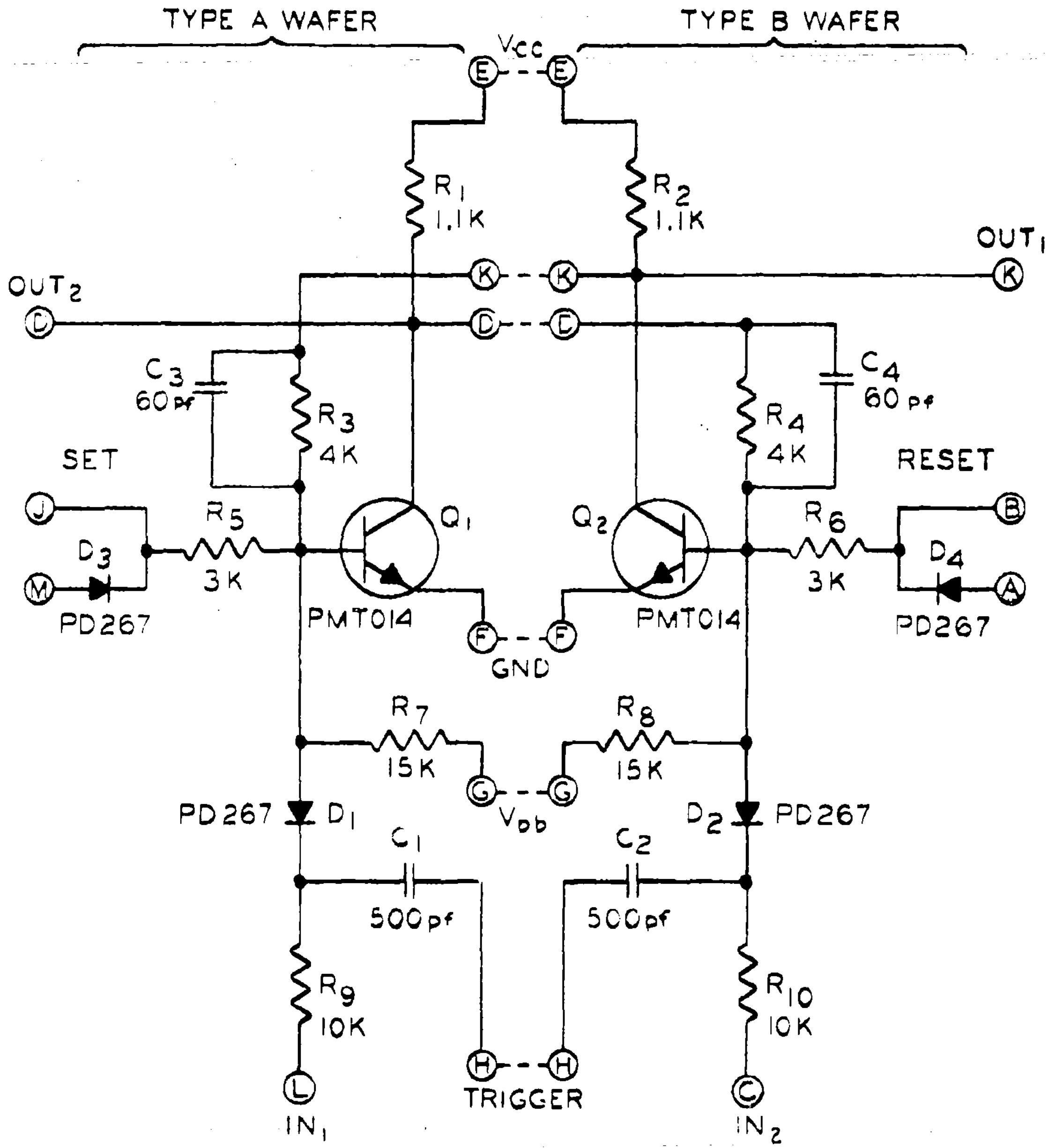


TRIGGER FLIP-FLOP SCHEMATIC DIAGRAM

Showing Division into Symmetric Halves

for Deposition on Two Wafers

Figure 6



R-S-T FLIP-FLOP SCHEMATIC DIAGRAM

Showing Division into Symmetric Halves for Deposition on Two Wafers

Figure 7

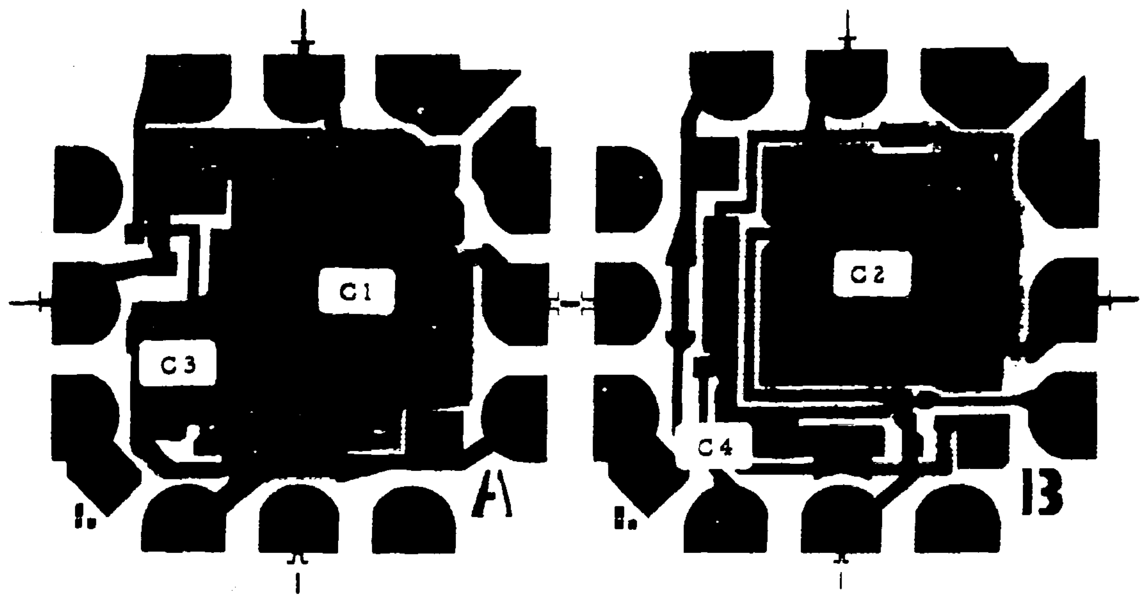


Figure 8a
Composite of all films in two-wafer R-S-T flip-flop
(Dielectric shown in half-tone for clarity.)

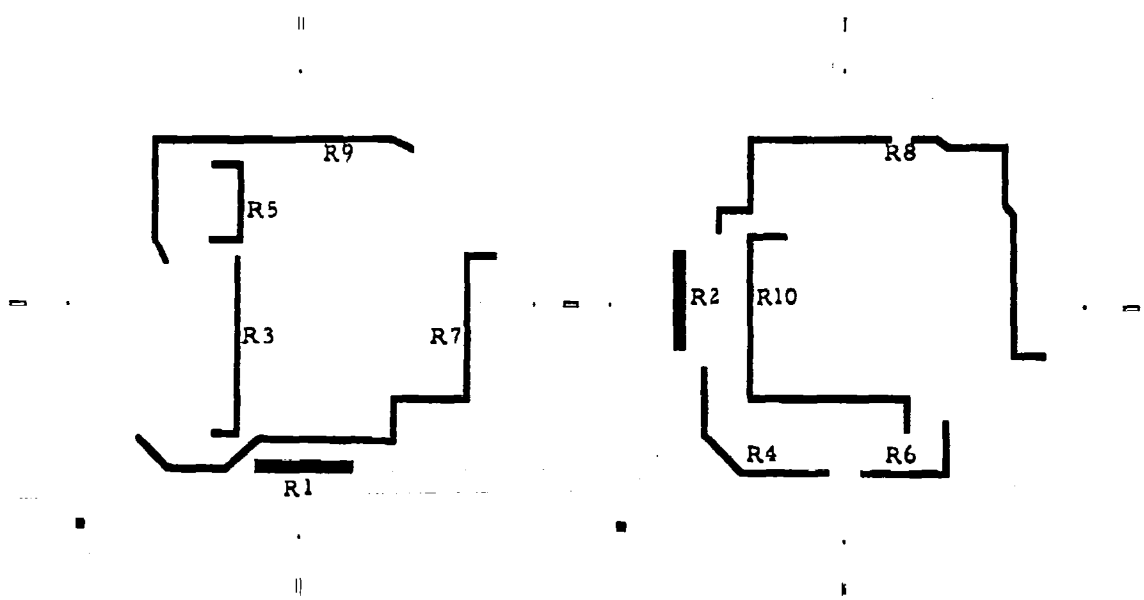


Figure 8b
Resistor Patterns

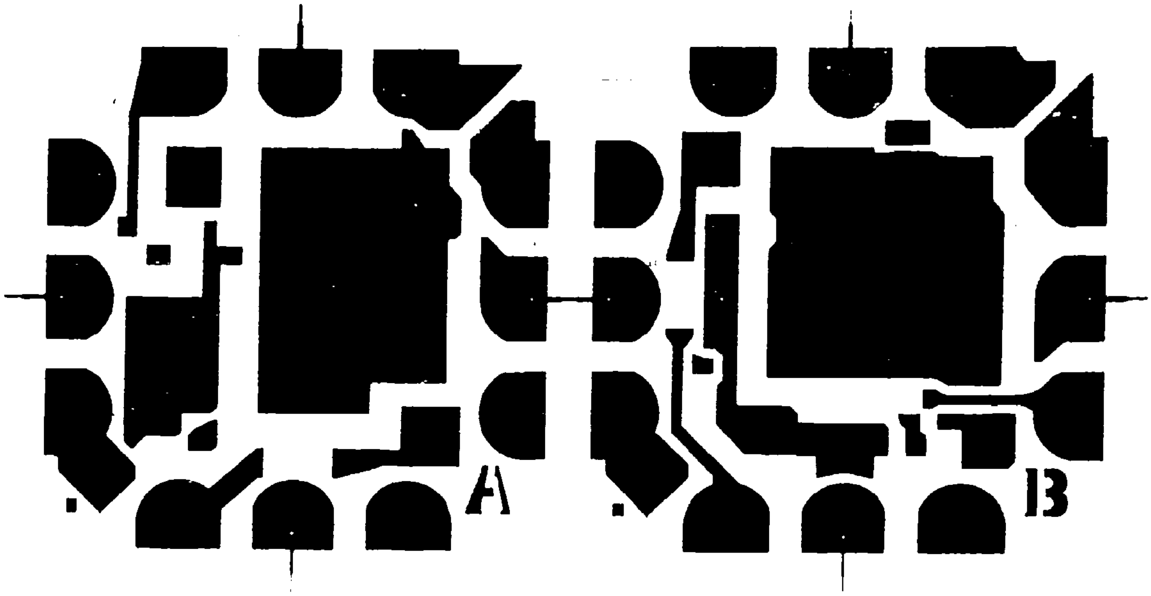


Figure 9 a
First Conductor Pattern

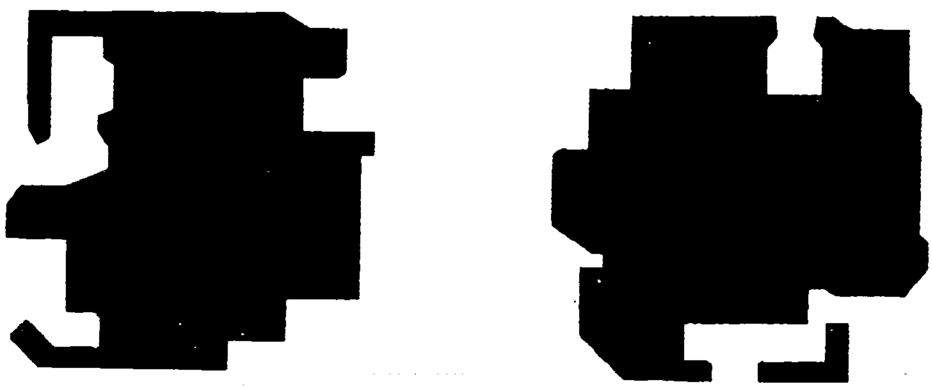


Figure 9 b
Dielectric Pattern

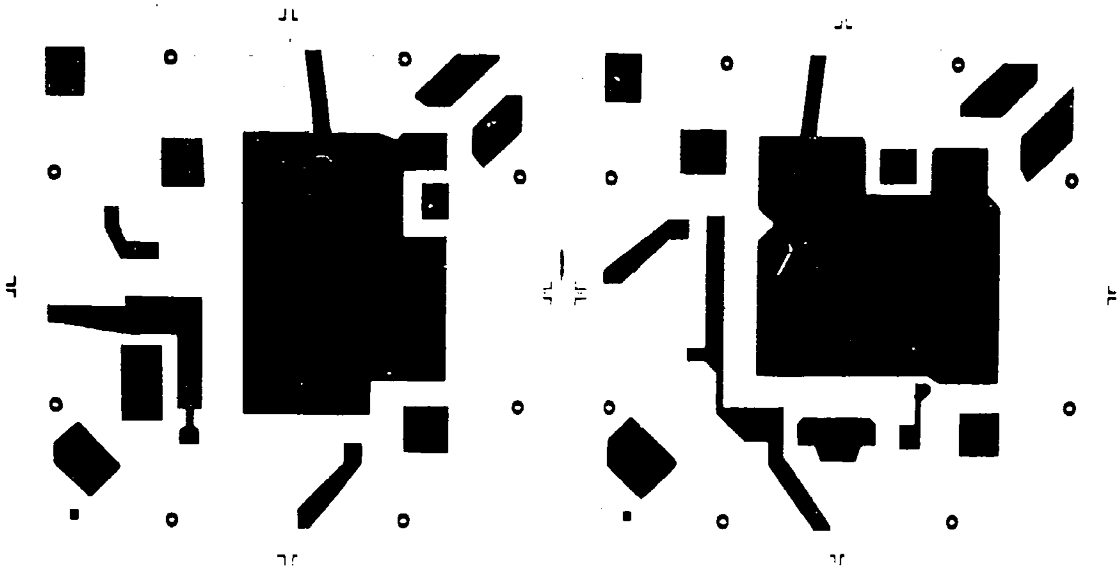


Figure 10a
Second Conductor Pattern for Configuration 1

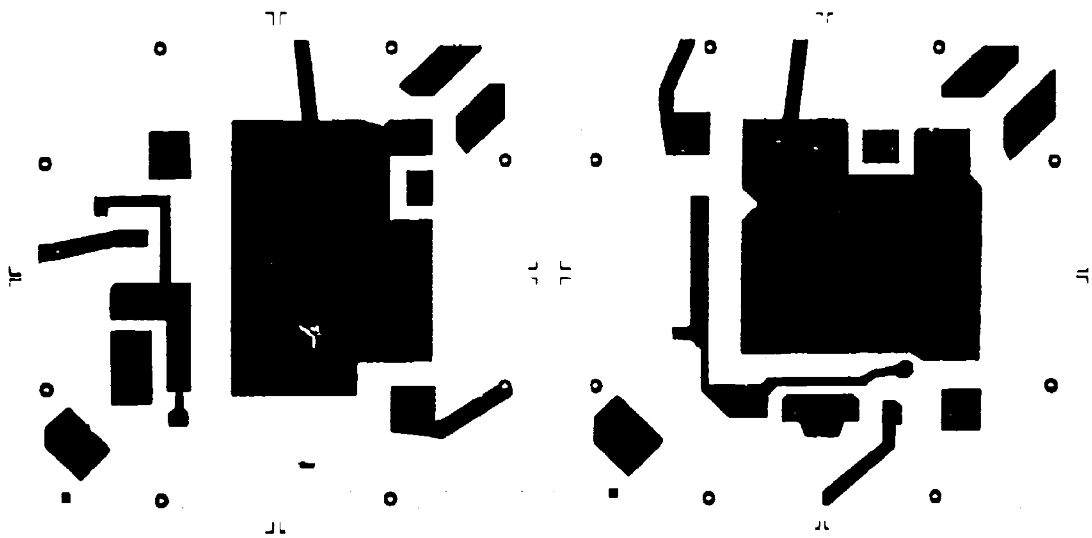
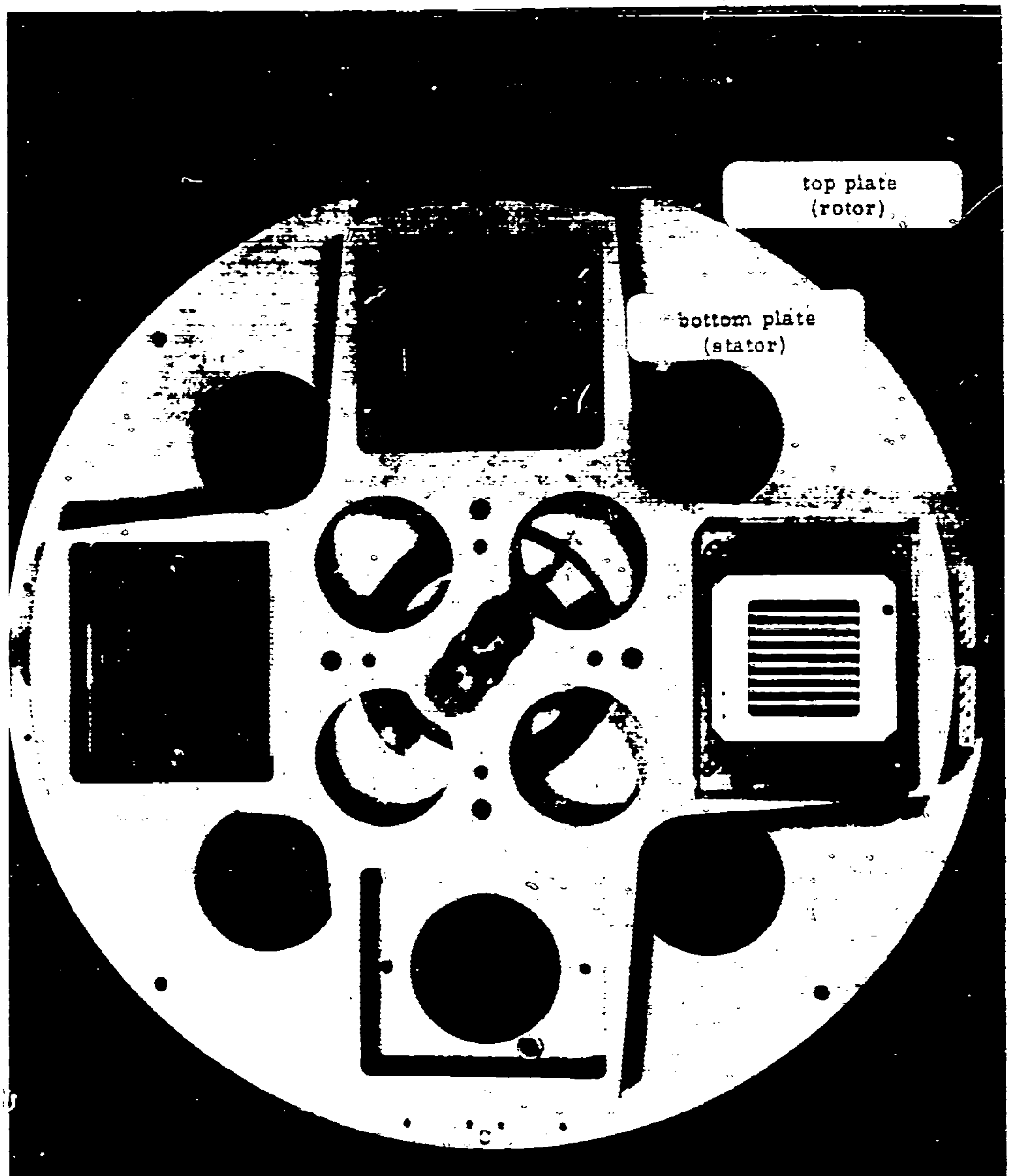


Figure 10b
Second Conductor Pattern for Configuration 2



MASK CHANGER

Figure 11

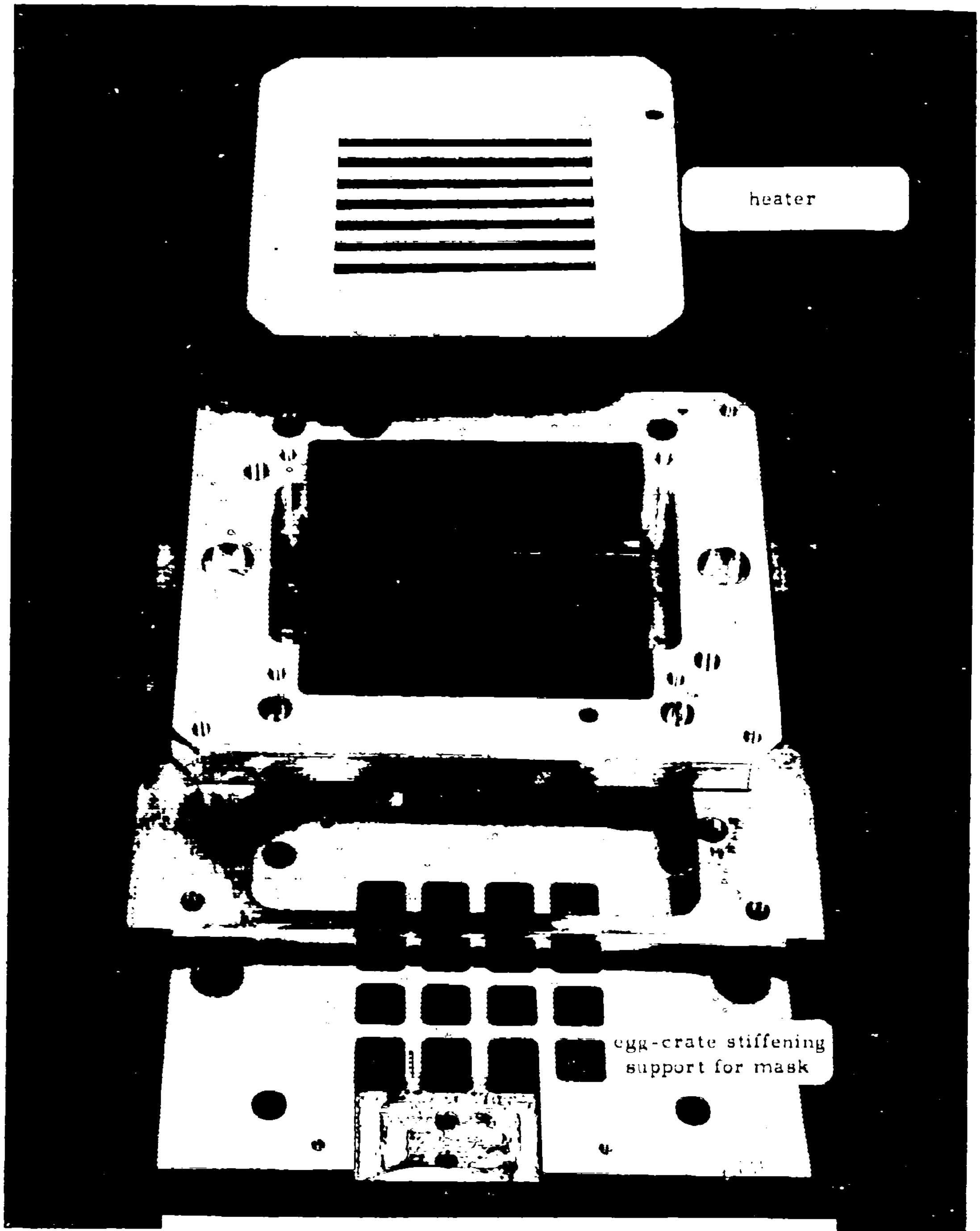


Figure 12 SUBSTRATE HEATER, AND MASK FIXTURES

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MICROELECTRONIC CIRCUITRY IN MICRO-MODULES
H. Weber, S. Weld, L. Gille

Second Quarterly Progress Report, 1 September 1961 to 31 November 1961, pp-Illus-Graphs, Signal Corps Contract DA-36-039-SC-87316, Task-3A99-15-002-03, Unclassified Report.

This report describes the steps undertaken in the microminiaturization of a Signal Corps air encoder subassembly previously manufactured from standard components. The subassembly is a shift register consisting of 28 flip-flops, 1 gate, and 3 driver circuits. These circuits are to be vacuum deposited on .310 inch square glass substrates and then stacked into micro-modules .625 inches in height.

The techniques involved in monitoring the vacuum deposition of all films are discussed. A nichrome film is used in the deposition of resistors. Gold is used for the conductor pattern, interconnections, and capacitor plates. Silicon monoxide forms the capacitor dielectric and is also used as a protective coating for the resistors. The addition of active elements is required to complete the deposited passive circuit.

Discussed in this report is a multiprobe jig which makes contact to 22 terminals of a deposited flip-flop. This jig allows each wafer to be operationally tested before the active elements are attached. Each passive element on the wafer can also be selected and measured under static conditions.

Also discussed, is a mask changer under fabrication during this reporting period. This is a device to allow the changing of four masks without breaking vacuum. Maximum accumulated mask registration tolerance is ±.003 inches.

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